Recent Developments & Future Directions in CCSDS Flight Dynamics Standards

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Introduction

- The Consultative Committee for Space Data Standards (CCSDS) Navigation Working Group (CNWG) develops international standards for use in space flight dynamics operations
- CNWG progress has been regularly presented at the ISSFD since 2004 (every 3-5 years):
  - 2004, 18th ISSFD: Martin-Mur, Tomas, et al., "Exchange of Standardized Flight Dynamics Data"
  - 2007, 20th ISSFD: Van Eepoel, John, et al., "Standardizing Navigation Data: A Status Update"
  - 2012, 23rd ISSFD: Berry, David S., et al., "Progress in Standardizing Flight Dynamics Data Exchange"
- Recent developments (since 2012) and future directions will be discussed in this presentation

Recent Developments: Document Status (1/4)

The Conjunction Data Message (CDM)

- Message format for exchanging S/C conjunction information
- Informs affected satellite operator(s) of space object conjunctions, facilitates response
- Published in June 2013, now in wide usage (USSTRATCOM, NASA/CARA, CNES, JAXA, ESA, Space Data Center, others)
- In 2018, CDM will be eligible for CCSDS required 5-year review
  - Possible outcomes are reconfirm, revise, or retire
  - Given wide usage, retirement seems highly unlikely

The Pointing Request Message (PRM)

- Enables exchange of S/C pointing requests in standard format
- Development of PRM document completed in mid-2016
- Draft standard in final prototyping phase prior to publication
  - "At least two independent and interoperable prototypes or implementations must have been developed and demonstrated in an operationally relevant environment, either real or simulated"
- PRM should be published in mid-2017

Recent Developments: Document Status (2/4)

The Navigation Hardware Message (NHM)

- Proposed standard for use in exchanging data from onboard sensor measurements involved in attitude/orbit determination
- NHM has reached a roadblock in its development
- May be subject to cancellation based on CCSDS rules:
  - Two prototypers necessary at project approval; currently have only one
  - ICDs now discouraged, but as written the NHM requires one
- No decision at Spring 2017 CCSDS Meetings - Orange Book?

The Spacecraft Maneuver Message (SMM)

- Proposed standard for exchanging maneuver info
- Development recently discontinued
- Factor in decision was probable need to inherit/duplicate much of Orbit Data Messages (ODM), Attitude Data Messages (ADM)
- Requirements developed for SMM refined/re-allocated to ODM/ADM, which have elementary maneuver specifications

Recent Developments: Document Status (3/4)

The Re-Entry Data Message (RDM)

- New standard started mid-2016
- Will contain information related to objects re-entering the atmosphere of a celestial body and impacting its surface
- Primarily Earth-centric, but other orbit centers not excluded
- Much RDM information is inherited from the CDM
- RDM is very early in development; it may progress quickly

The Events Message (EVM)

- "Events Message" (EVM) was introduced and discussed in the 2012 progress report, but it has not yet started
- Predicted orbital events describe when and possibly how some situations (generally related to a satellite) occur
- No standard yet exists for predicted orbital events
- CNWG has been working with another CCSDS working group also interested in orbital events
- Decision to activate EVM was made at Spring 2017 CCSDS Mtgs

Recent Developments: Document Status (4/4)

"First Generation" Standards

- The "first generation" CNWG standards (the ODM, ADM, and Tracking Data Message (TDM)) are being revised
- In each case, periodic review led to a decision to *revise*
- As part of ODM revisions, a new Orbit Comprehensive Message (OCM) responding to new use cases, will be added
- OCM adds ability to describe force models, orbit determination description, state transition matrices, more detailed info about translational maneuvers than can be conveyed in simpler OPM
- During ADM revisions, an analogous "Attitude Comprehensive Message" (ACM) is contemplated to implement requirements related to rotational maneuvers
- Revised TDM Agency Review planned in late 2017/early 2018; includes a few new data types and XML formatting material
- A second TDM revision will be started almost immediately
- Navigation Data Messages XML Spec (NDM/XML) describing ODM, ADM, and TDM in XML format, is also being revised

Future Directions (1/5)

- Future directions focus on a few topics arising in the context of "second generation" CNWG standards (CDM, PRM, RDM, ...)
- Also, new use cases have been arising on a fairly regular basis
- Some CCSDS policy changes have affected CNWG directions
- Together, these have exposed several issues, specifically, the closely related topics of inheritance, duplication, consistency

Inheritance and Duplication

- The need to duplicate common data structures often arises
- Many data items that appear in ODM also relevant to the CDM
- Much of the information in the RDM is inherited from the CDM
- Not necessarily a problem; however, Lead Editors are sometimes tempted to slightly modify inherited structures
- This modification could be interpreted by users of the standards as a failure to achieve the desired consistency

Future Directions (2/5)

Consistency and CCSDS Objectives

- Two important CCSDS objectives: cross-support, interoperability
- There is evidence that consistency is expected by users
- CNWG Guideline: new standards should be as consistent as possible with existing standards; avoid duplication of material
- Where data structures must be duplicated they should be consistent unless there is a very good reason to diverge
- Emerson: "a foolish consistency is the hobgoblin of little minds"
- Operative word here is "foolish"; in developing international standards consistency between related standards is not foolish!
- Still, the effort to maintain consistency is a constant challenge
- CNWG now has 7 standards documents in progress, 6 different Lead Editors, 100% membership turnover within past 15 years
- Membership turnover brings fresh ideas, but complicates effort to maintain consistency with past products (especially revisions)
- 2004 "ODM convention" represents constraint, blocks progress

Future Directions (3/5)

The "Navigation Functional Message"

- In late 2014, consistency and duplication topics led to an informal proposal: a "universal, modular message"
- Tentatively called the "Navigation Functional Message" or NFM
- One might characterize this notion as related to "The Lego® System", i.e., standardized combinable message blocks
- Challenge: to allow the transformation of a jumble of trajectory, attitude, maneuver, and tracking "building blocks" into a message that is technically useful for flight dynamicists
- The concept of the "combined instantiation" already exists in the NDM/XML specifications standard
- Combined instantiation allows a variety of "scenarios" to be exchanged in a single flight dynamics data message
- Potential drawback: might make development of converters from international exchange format to internal formats harder
- Additional discussions held during Spring 2017 CCSDS meetings

Future Directions (4/5)

The SANA Registry

- The CCSDS Space Assigned Numbers Authority (SANA) provides a single, CCSDS-wide, central location to register "a variety of standards-related information ... that is used across CCSDS"
- In principle, a SANA Registry is more flexibly modified than a document if something needs to be corrected, clarified, added, or deleted
- CNWG is considering registries that would be more dynamic, contribute to greater consistency, and eliminate need for some normative document annexes, for example:
  - Single source of Time Systems that may be used in messages
  - Single source of Reference Frames that may be used in messages

Future Directions (5/5)

Draft Projects

- Officially, CCSDS Working Groups "are chartered to produce specific standards on a specific schedule and within specific resource envelopes, and then go out of business"
- However, recently there is a greater emphasis on a longer view
- Working group chairs are asked to "update your 5 year plans", and create "draft projects" as part of the CCSDS Strategic Plan
- Draft projects are essentially proposals for future work to be undertaken by working groups
- Somewhat contradicts the notion of "going out of business"
- 18 of 23 CCSDS working groups have 1 or more draft projects
- CNWG has 3 such draft projects, a "Launch Data Message", "Fragmentation Data Message", and "Events Message".
- RDM was a draft project for a couple of years
- RDM is now an active project, Events Message will start soon
- An NFM draft project was a possible outcome of Spring 2017 CCSDS Meetings, but it is not yet well enough defined

Conclusion

- We have described a few recent developments and future directions of the CCSDS Navigation Working Group
- A few other less mature future ideas have also been proposed/suggested
- CCSDS meets twice annually; in each CCSDS Navigation WG Meeting series, some agenda time is allocated to future topics
- Some of these mature further and may find their way into an international standard; some do not survive

- Since last ISSFD status update in 2012, CCSDS Navigation Working Group has been diligently engaged in the development of international standards that we hope are useful in interoperable, cross-supported space flight dynamics operations

The CCSDS Navigation WG (Rome 2016)

The CCSDS Navigation WG (San Antonio 2017)